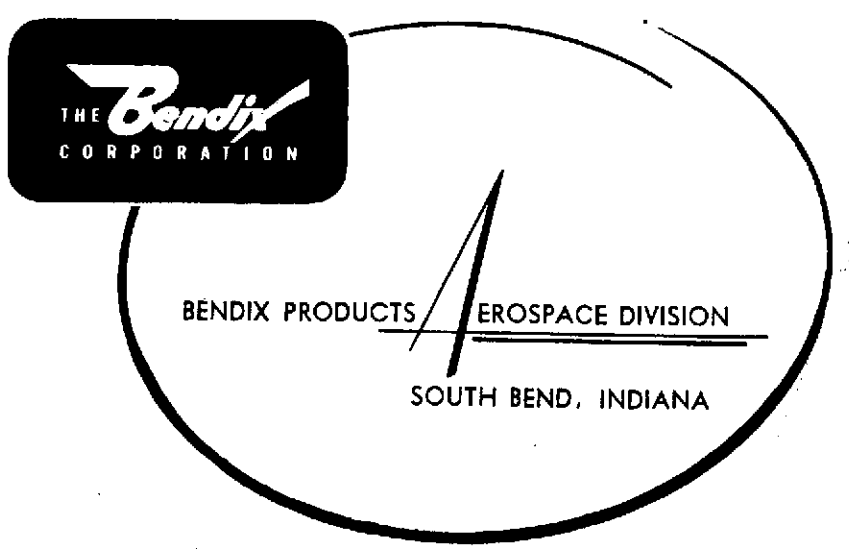
REPORT NO. BPAD-863-4-15184R

DOCUMENT CONTROL NO. DC-3864

BOOK NO. 21

TURBINE POWER CONTROL VALVE ACTUATOR MODEL NT-C2 PART NO. 2775022, SERIAL NO. 13

TEST DATA AND RESULTS (U)



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Report No. BPAD-863-4-15184R
DC No. 3864

Turbine Power Control Valve Actuator
Model NT-C2
Part No. 2775022
Serial No. 13

Test Data and Results

November 1963

Submitted To Aerojet General Corporation
Azusa, California

Prepared by

Aerospace Nuclear and Pneumatic Controls Department
Bendix Products Aerospace Division of The Bendix Corporation
South Bend 20, Indiana

Prepared Under the Direction of: J. R. Doussard

J. R. Doussard, Project Engineer

Approved by: D. W. Howard

D. W. Howard
Nerva Controls

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SECTION I

INTRODUCTION

This report presents the results of the tests performed to evaluate the Turbine Power Control Valve Actuator, Model NT-C2, Part Number 2775022, Serial Number 13. All tests were conducted at the facilities of the Bendix Products Aerospace Division, South Bend, Indiana, during September and October 1963.

The test program included component evaluation tests, actuator performance tests at room temperature, performance tests at low temperature, and final calibration before shipment. Reproductions of actual actuator performance test data are included in this report.

The actuator was shipped to the Aerojet General Corporation on October 24, 1963.

SECTION II

COMPONENTS AND TEST RESULTS

2.1 MAGNETIC AMPLIFIER (Part Number 2775020, Serial Number 8)

The schematic diagram of this amplifier, after system compensation, is shown in Figure 2-1.

2.2 TORQUE MOTOR (Part Number 2151818, Serial Number 116, Midwestern Instrument Corporation, Model 39-3A)

Figure 2-2 is a plot of the frequency response of the torque motor tested with a constant flapper displacement amplitude of .001 inch.

Figure 2-3 shows the displacement sensitivity of this torque motor.

2.3 SERVO VALVE (Part Number 2775006, Serial Number 2)

Figure 2-4 is a plot of the deadended pressure of the P_1 and P_2 ports of the servo valve versus the differential current to a torque motor.

Figure 2-5 shows the static flow sensitivity of the valve when exhausted to atmosphere.

2.4 GEAR MOTOR (Part Number 2775009, Serial Number 13)

Two curves of the characteristics of the gear motor - servo valve - torque motor combination are presented.

Figure 2-6 is a plot of the no-load speed of the gear motor versus the differential current supplied to the torque motor.

Figure 2-7 is a plot of the stalled motor torque versus the differential current supplied to the torque motor.

2.5 TRANSMISSION (Part Number 2775025, Serial Number 3)

The following characteristics apply to this transmission:

Efficiency	80.0 percent at 1000 rpm with a torsional load of 370 in/lbs on the output shaft
	83.0 percent at 1000 rpm with a torsional load of 740 in/lbs applied to the output shaft
Breakout Torque	1.0 to 2.0 in. oz. on input shaft
Backlash (on output shaft)	not measurable
Stiffness (measured with 150 in/lbs load on output shaft)	55,500 in/lbs per radian.

2.6 POTENTIOMETERS (Part Number 2775306. Feedback Potentiometer Serial Number 341357. Instrumentation Potentiometer Serial Number 341361)

Figure 2-8 shows the relationship between the potentiometer voltages and the actuator output shaft position.

Both potentiometers have been tested at room temperature and at low temperatures down to -315°F. Performance was satisfactory at these temperature levels.

2.7 DYNAMIC SEAL

The dynamic shaft seal is an assembly composed of a Hastelloy X seal surface, plated with a dry lubricant film and supported by Inconel X bellows, mated against a Linde LC-1C flame-sprayed, modified-chromium carbide surface. Identical seals have been tested and found to withstand the 600 psi pressure drop in the forward direction at temperatures up to and exceeding 1200°F.

2.8 THERMOCOUPLES

Five iron-constantan thermocouples have been installed in this actuator to facilitate temperature measurements at various points through the actuator. Four of the thermocouples are located as shown in Figure 2-9. The fifth thermocouple is located on the electrical connector on the inside of the actuator. This thermocouple is TC No. 13. All thermocouples have a common iron wire connected to pin, No. 11, of the connector. The number designation of the thermocouples shown in Figure 2-9 corresponds to the electrical connector pins to which the constantan wires of these thermocouples are connected. When a temperature gradient exists over the electrical connector, the thermocouple readings will be biased, due to the second function formed at the connector. The amount of bias will depend on the material of the wire used from the connector to the temperature recorder. Thermocouple No. 13, located on the connector on the inside of the actuator can be used to detect temperature gradients over the connector.

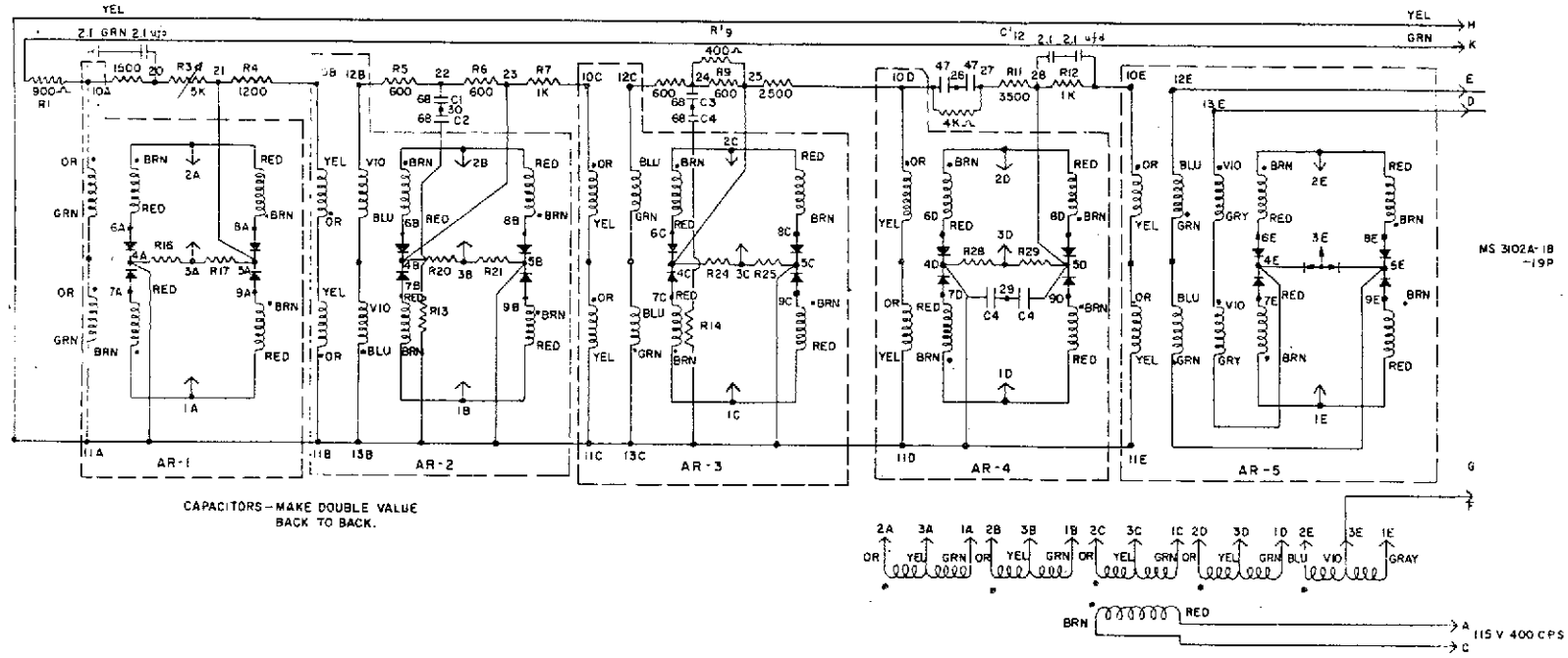


Figure 2-1. Magnetic Amplifier, P/N 2775020, S/N 8

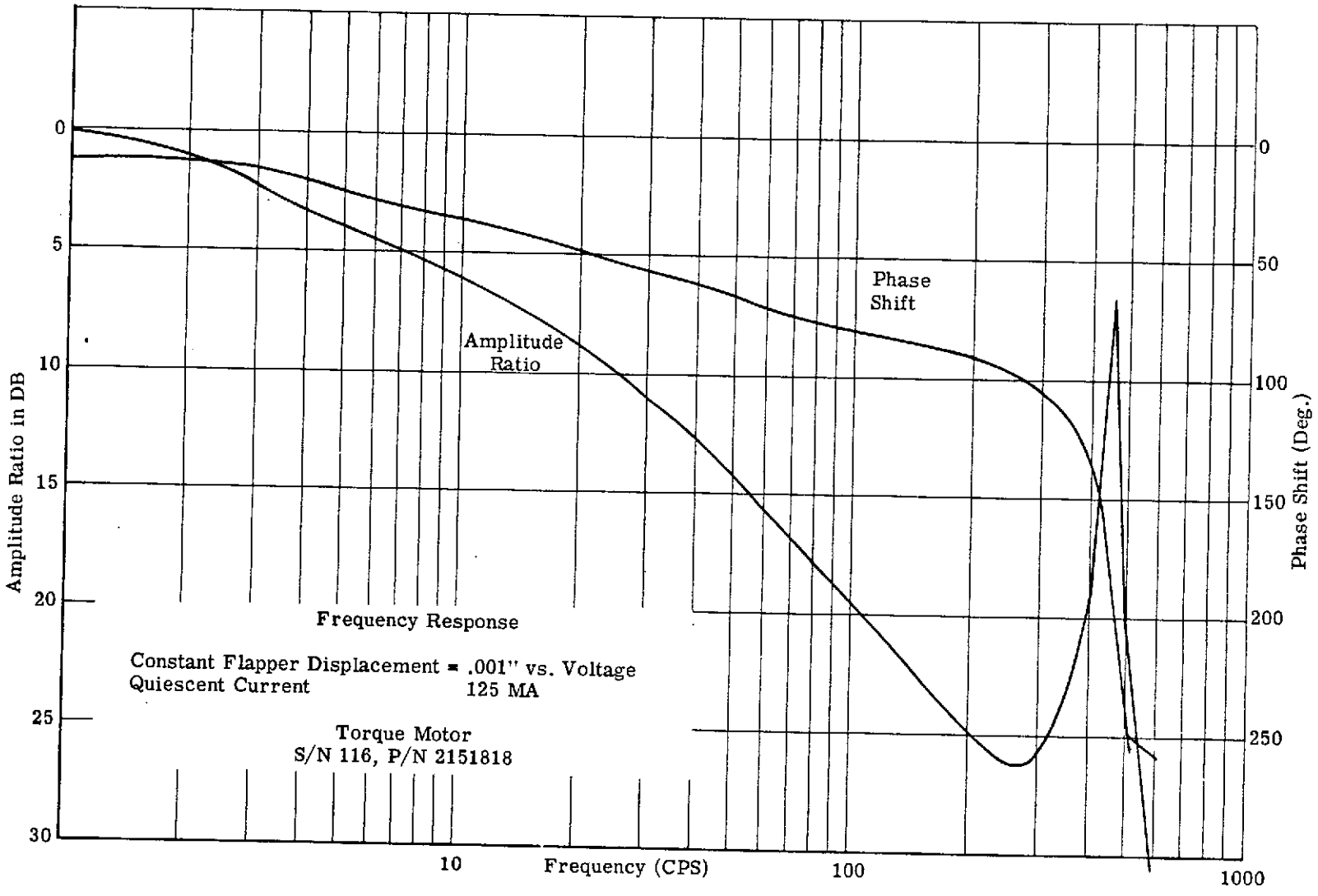


Figure 2-2. Frequency Response - Constant Flapper Displacement Versus Voltage

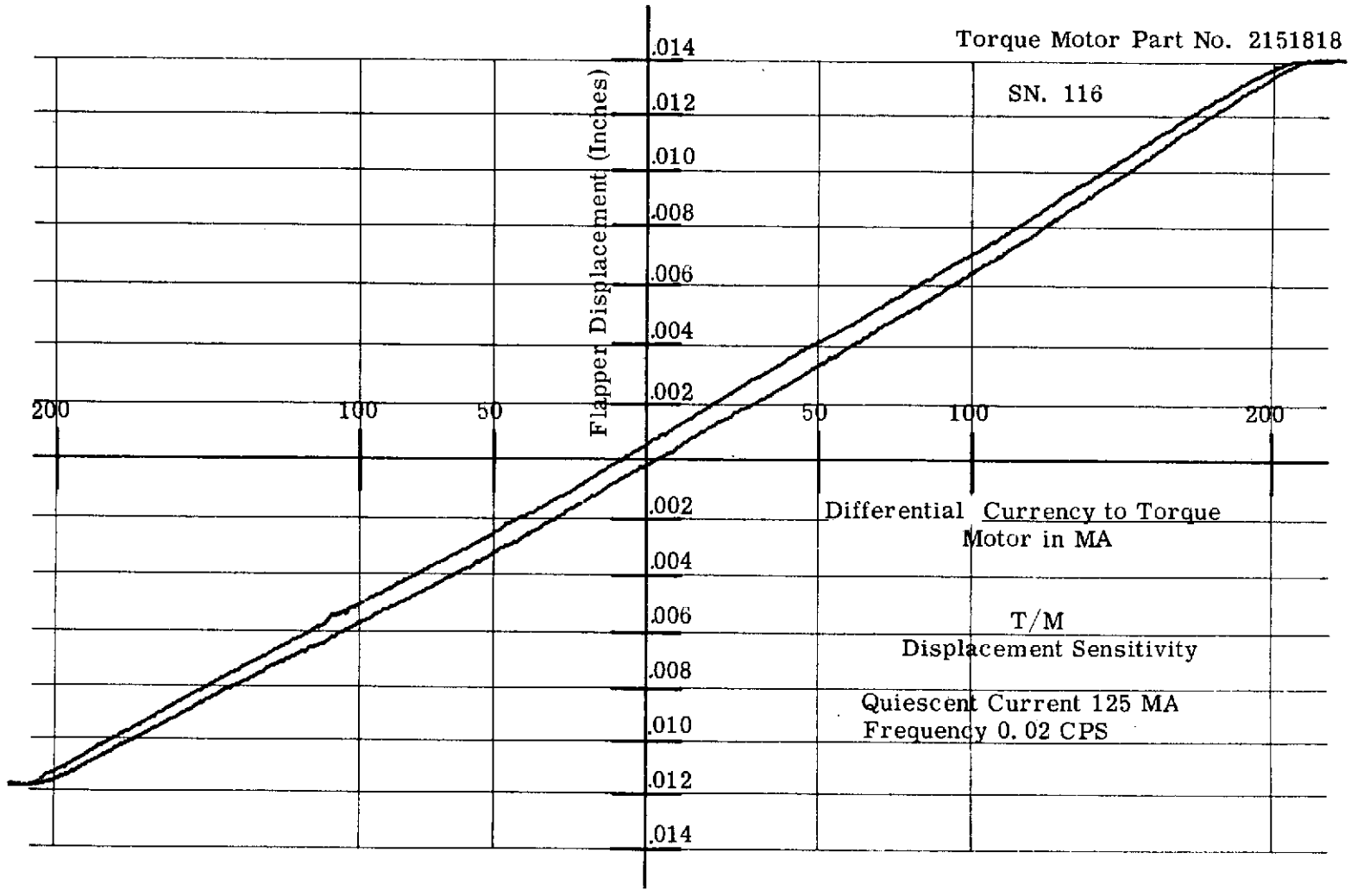


Figure 2-3. Flapper Displacement Versus Differential Current Supplied To Torque Motor

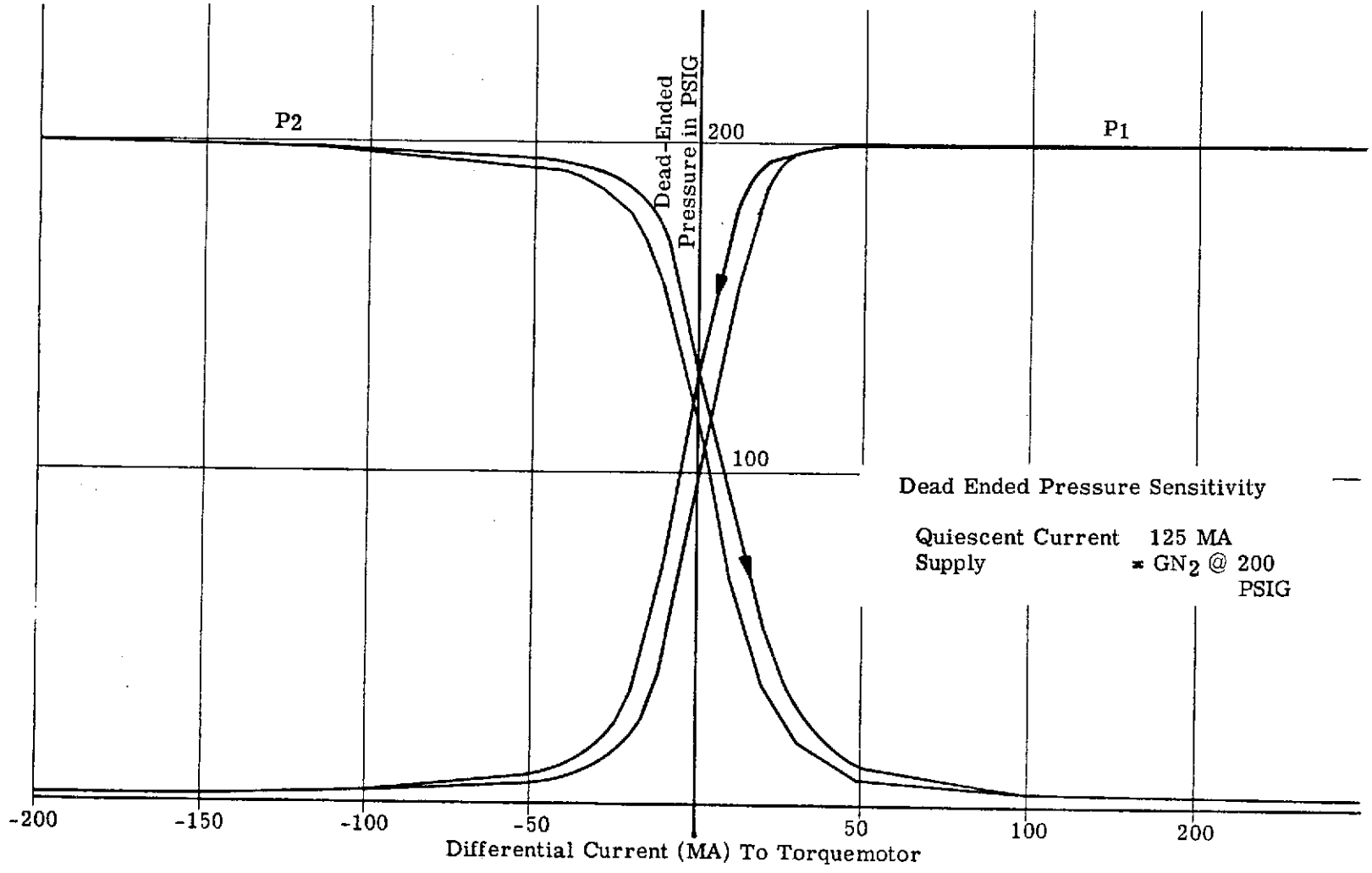


Figure 2-4. Dead-Ended Pressure Sensitivity

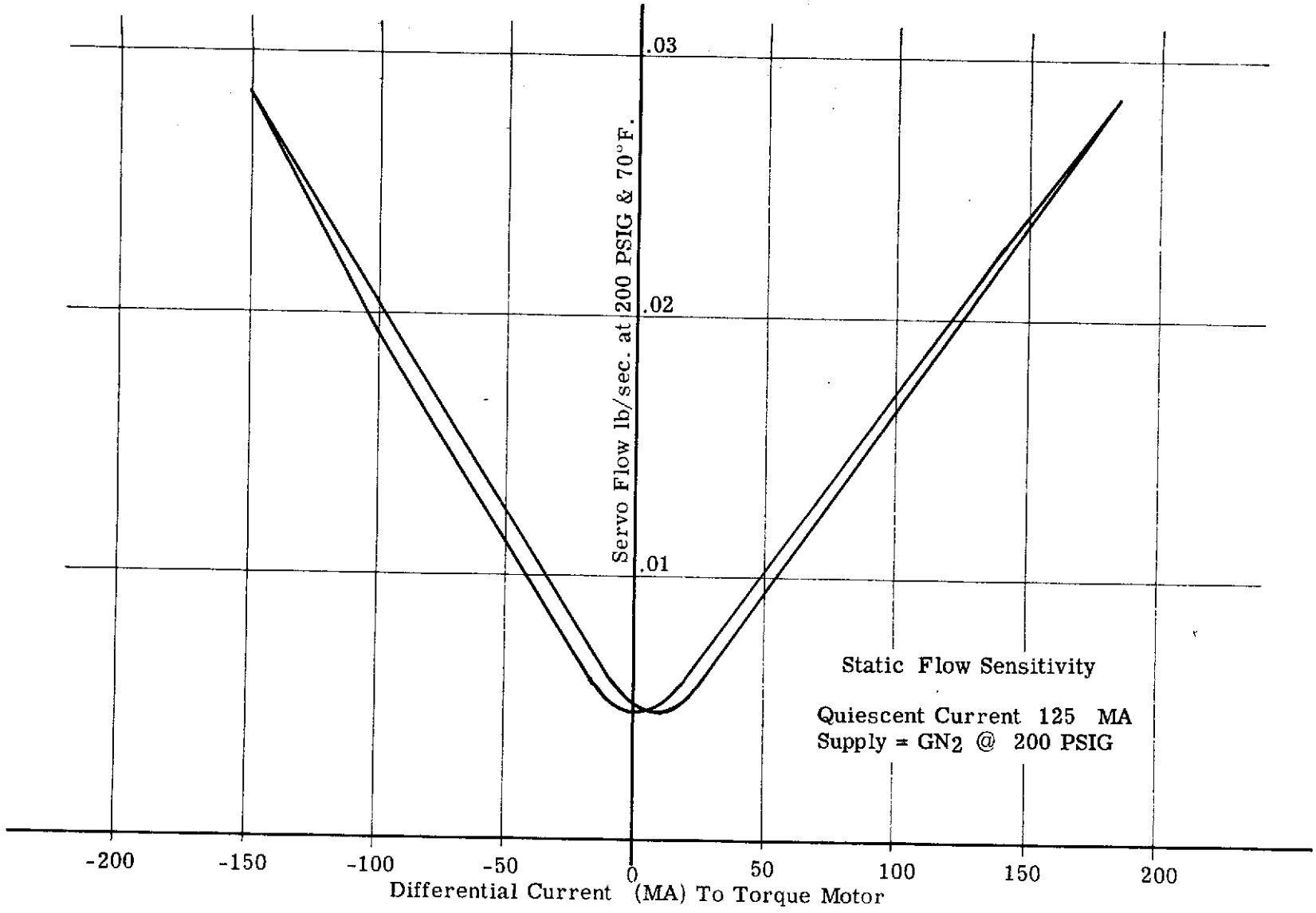


Figure 2-5. Nitrogen Flow Versus Differential Current Supplied To Torque Motor

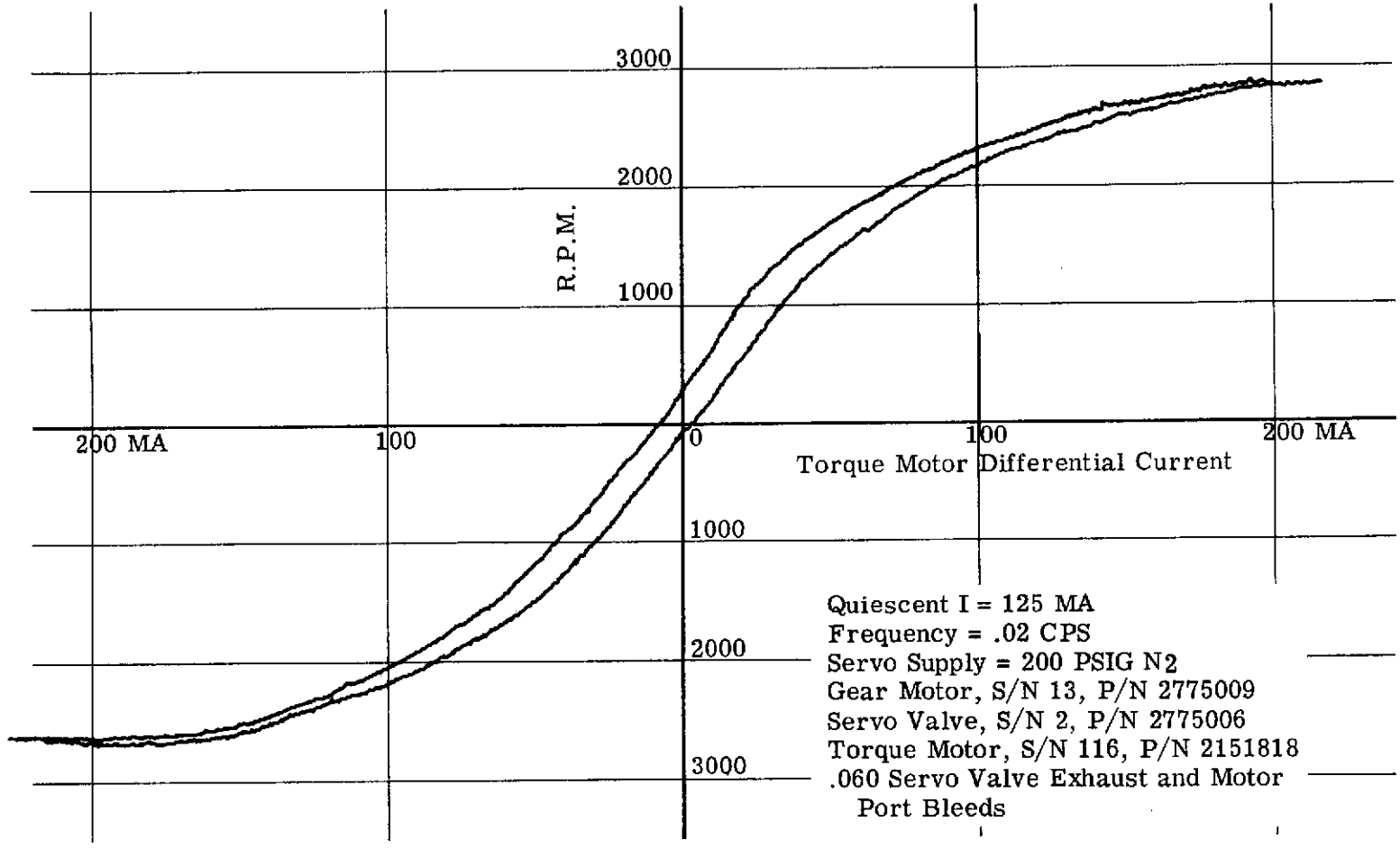


Figure 2-6. No-Load Speed Versus Differential Current

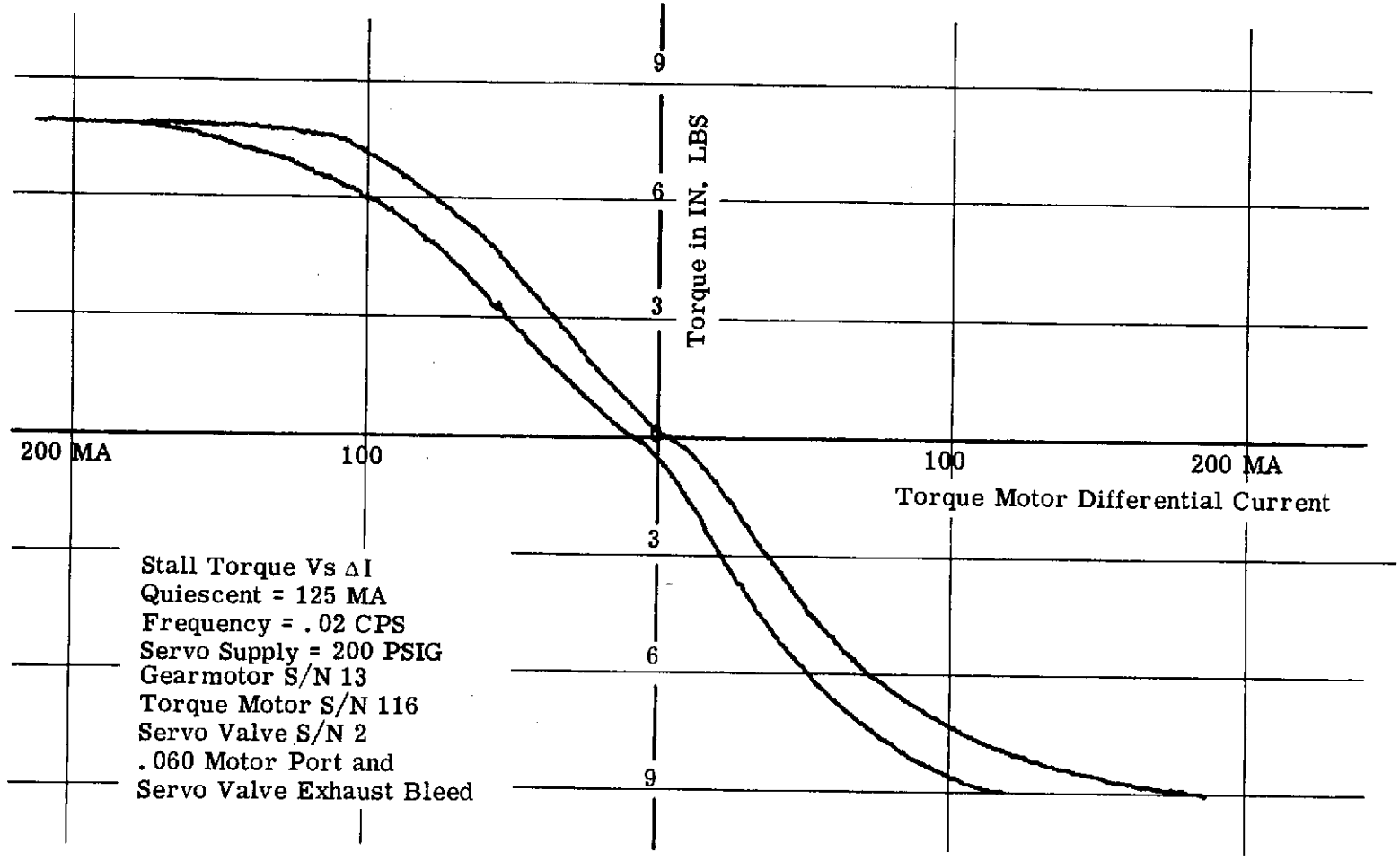


Figure 2-7. Stall Torque Versus Differential Current

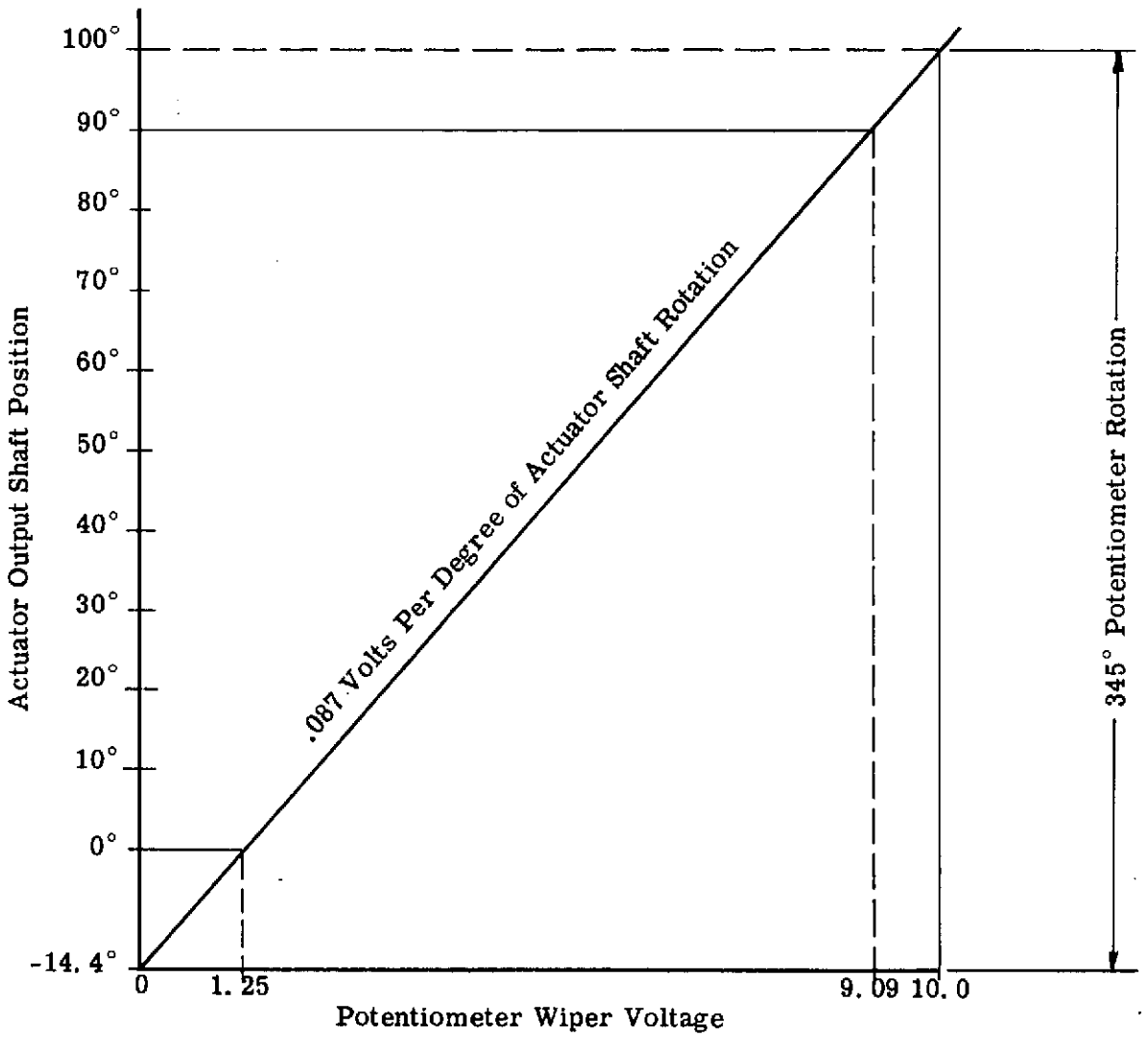


Figure 2-8. Relationship at Potentiometer Voltage and Actuator Shaft Position

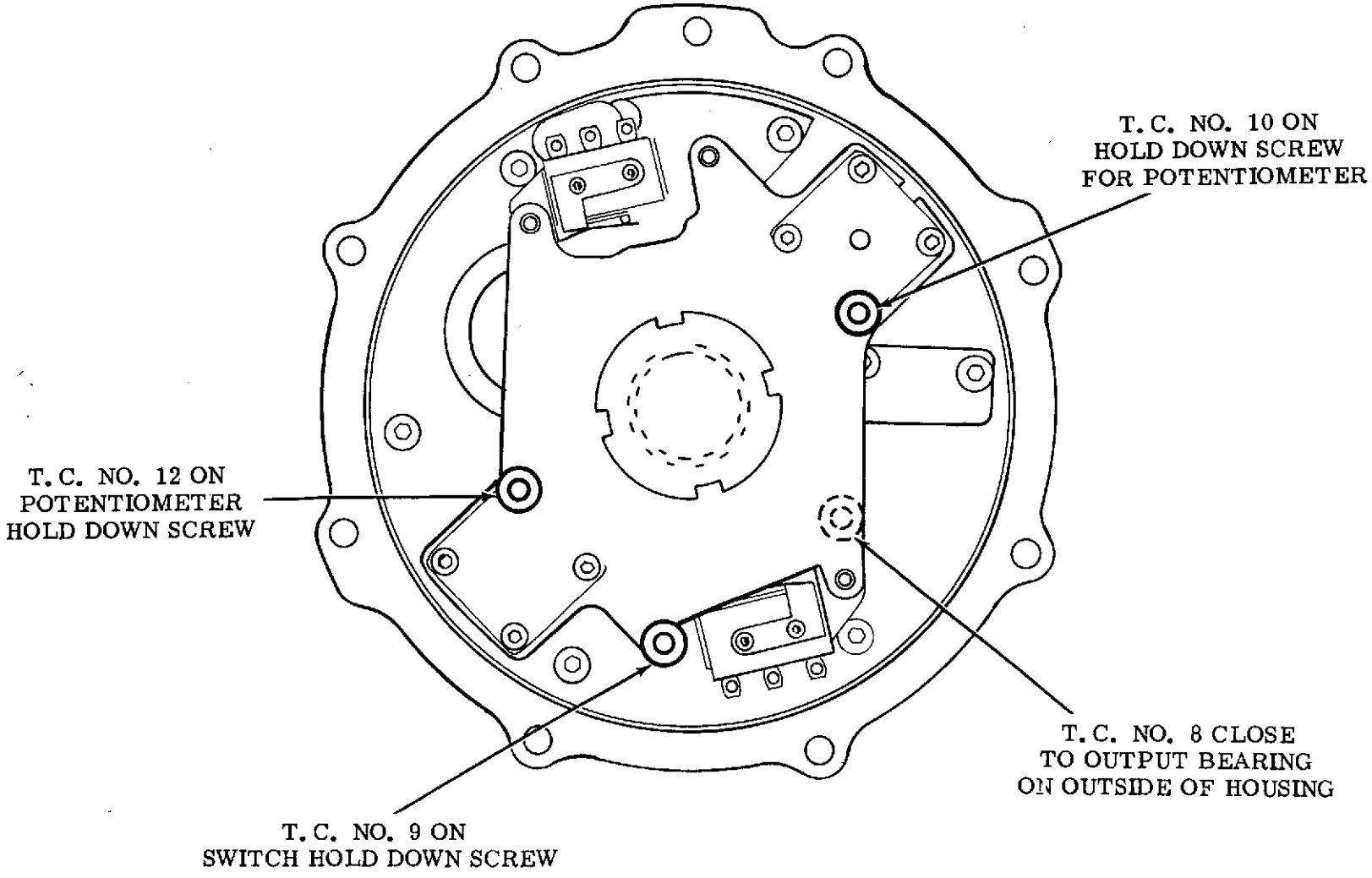


Figure 2-9. Locations of Thermocouples

SECTION III

PERFORMANCE TESTING

After all component testing was completed, the actuator was assembled and tested as a system. The actuator performance was compared to the performance criteria in Paragraph 3.1.

3.1 PERFORMANCE CRITERIA

3.1.1 Transient Response

The response of the actuator to an input step amplitude equal to 45 degrees from any actuator output shaft position greater than 5 degrees shall be such that 62 percent of the corresponding output level shall be achieved within 0.12 second. Following a transient disturbance to the input of the actuator, the overshoot of the output shaft motion shall not exceed 20 percent of the ordered output level and the output shaft position shall be restrained to within 5 percent of the ordered step within 0.3 second.

3.1.2 Slew Velocity

Under loaded conditions, the slew velocity shall be 360°/second minimum.

3.1.3 Dynamic Resolution

The resolution of the actuator shall be ±0.5 degree from the ordered position when the actuator is driven with a one-degree per second ramp at 0.05 cps. When coupled to the Turbine Power Control Valve, the resolution requirement is effective in the 5° to 90° actuator output shaft position range.

3.1.4 Frequency Response

The response of the actuator to a sinusoidal input signal of ±2 degrees amplitude shall approximate a second order system with a break point at a nominal 8 cps with a 0.5 damping ratio minimum.

3.2 ACTUATOR SYSTEM PERFORMANCE TESTS

Table I summarizes all the performance testing and test results obtained on the actuator system. The test conditions are shown in Table II. Reproductions of the actual Sanborn recorder traces taken during the testing are shown in Figures 3-1 through 3-9.

3.3 FINAL CALIBRATION BEFORE SHIPMENT

Before shipment, the actuator was recalibrated. Actual Sanborn recorder traces of these tests are reproduced in Figure 3-10.

3.4 TOTAL ACCUMMULATED TEST TIME

The total accummulated test time on the actuator assembly was 6.5 hours. Time accummulated on the individual components before they were combined into the actuator assembly was as follows:

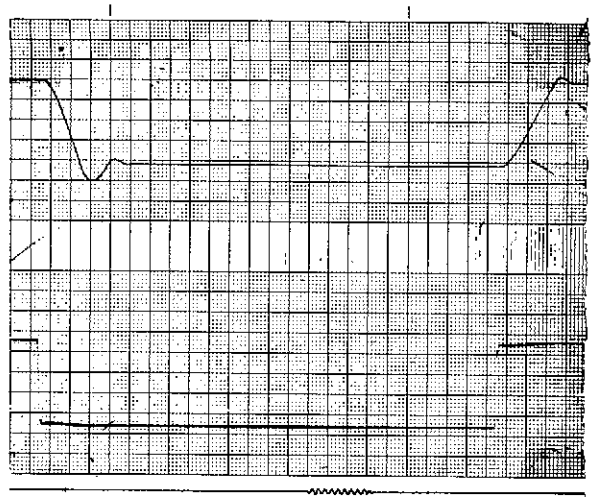
Torque Motor, P/N 2151818, S/N 116	3.7 hours
Servo Valve, P/N 2775006, S/N 2	18.5 hours
Gear Motor, P/N 2775009, S/N 13	9.0 hours
Transmission, P/N 2775023, S/N 3	0.8 hours

TABLE I
SUMMARY OF TESTS AND TEST RESULTS

Test	Test Condition	Forcing Function	Test Results	Figure Number
Transient Response	A	45° step at 0.3 cps Around 42°	Overshoot 19% 62% rise time 0.08 sec. Settling time 0.21 sec.	3-1A
Slew Velocity	A	45° step at 0.3 cps Around 42°	384°/sec. increase angle 556°/sec. decrease angle	3-1A
Static Resolution	A	0.1 cps sine wave Around 30°	Resolution ±0.085 deg.	3-1B
Dynamic Resolution	A	±5° ramp at 0.05 cps Around 30°	Resolution ±0.2°	3-1C
Frequency Response	A	±2° sine wave Around 30°	90° phase shift at 11 cps 180° phase shift at 16 cps	3-2 3-3
Dynamic Resolution	A	±5° ramp at 0.05 cps Around 60°	Resolution ±0.25°	3-4A
Static Resolution	A	0.1 cps sine wave Around 60°	Resolution ±0.08 deg.	3-4B
Frequency Response	A	±2° sine wave Around 60°	90° phase shift at 11 cps 180° phase shift at 18 cps	3-5 3-6
Transient Response	B	45° step at 0.3 cps Around 42°	Overshoot 2.4% 62% rise time 0.130 Settling time 0.250 sec.	3-7A
Slew Velocity	B	45° step at 0.3 cps Around 42°	232°/sec. increasing angle 476°/sec. decreasing angle	3-7A
Static Resolution	B	0.1 cps sine wave Around 30°	Resolution ±0.05°	3-7B
Dynamic Resolution	B	±5° ramp at 0.05 cps Around 30°	Resolution ±0.25°	3-7C
Frequency Response	B	±2° sine wave Around 30°	90° phase shift at 12 cps 180° phase shift at 22 cps	3-8 3-9

TABLE II
TEST CONDITIONS

Test Condition	External Friction Load (In-Lb.)	Torsional Spring Rate (In-Lb/Deg.)	Shaft Seal Pressure (PSIG)	Actuator Exhaust Back Pressure (PSIG)	Gas Exhaust Temperature (°F)	Gas
A	0	2.67	650	45	72	Hydrogen
B	0	2.67	650	45	72	Nitrogen

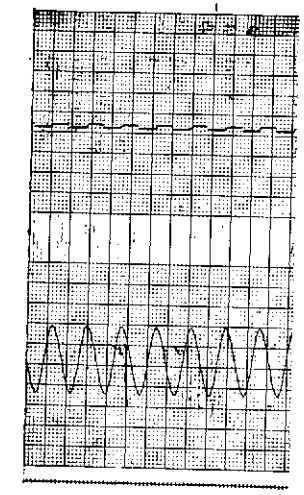


OUTPUT SHAFT POSITION: 2.0 DEGREES/MM

STEADY STATE OUTPUT SHAFT POSITION 42°

INPUT COMMAND SIGNAL: 45 DEGREE STEP

A TRANSIENT RESPONSE AND SLEW VELOCITY
PAPER SPEED: 100 MM/SEC

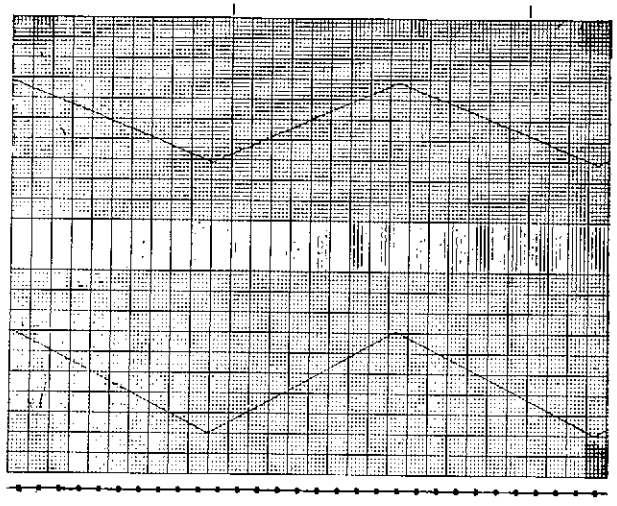


OUTPUT SHAFT POSITION: 0.01 DEGREE/MM

STEADY STATE OUTPUT SHAFT POSITION: 30°

INPUT COMMAND SIGNAL: ±0.085 DEG 0.1 CPS SINE WAVE

B STATIC RESOLUTION
PAPER SPEED: 1 MM/SEC



OUTPUT SHAFT POSITION: 0.5 DEGREE/MM

STEADY STATE OUTPUT SHAFT POSITION: 30°

INPUT COMMAND SIGNAL: ± 5 DEGREE RAMP AT 0.05 CPS

C DYNAMIC RESOLUTION
PAPER SPEED: 5 MM/SEC

FRICTION LOAD:	0 IN.-LB	LOAD SPRING RATE:	2.67 IN.-LB/DEG
EXHAUST PRESSURE:	45 PSIG	GAS:	HYDROGEN
SHAFT SEAL PRESSURE:	650 PSIG	GAS TEMPERATURE:	72°F
		SUPPLY PRESSURE:	200 PSIG

Figure 3-1. Closed-Loop Performance at TPCV Actuator NT-C2, S/N 13 - Test Condition A

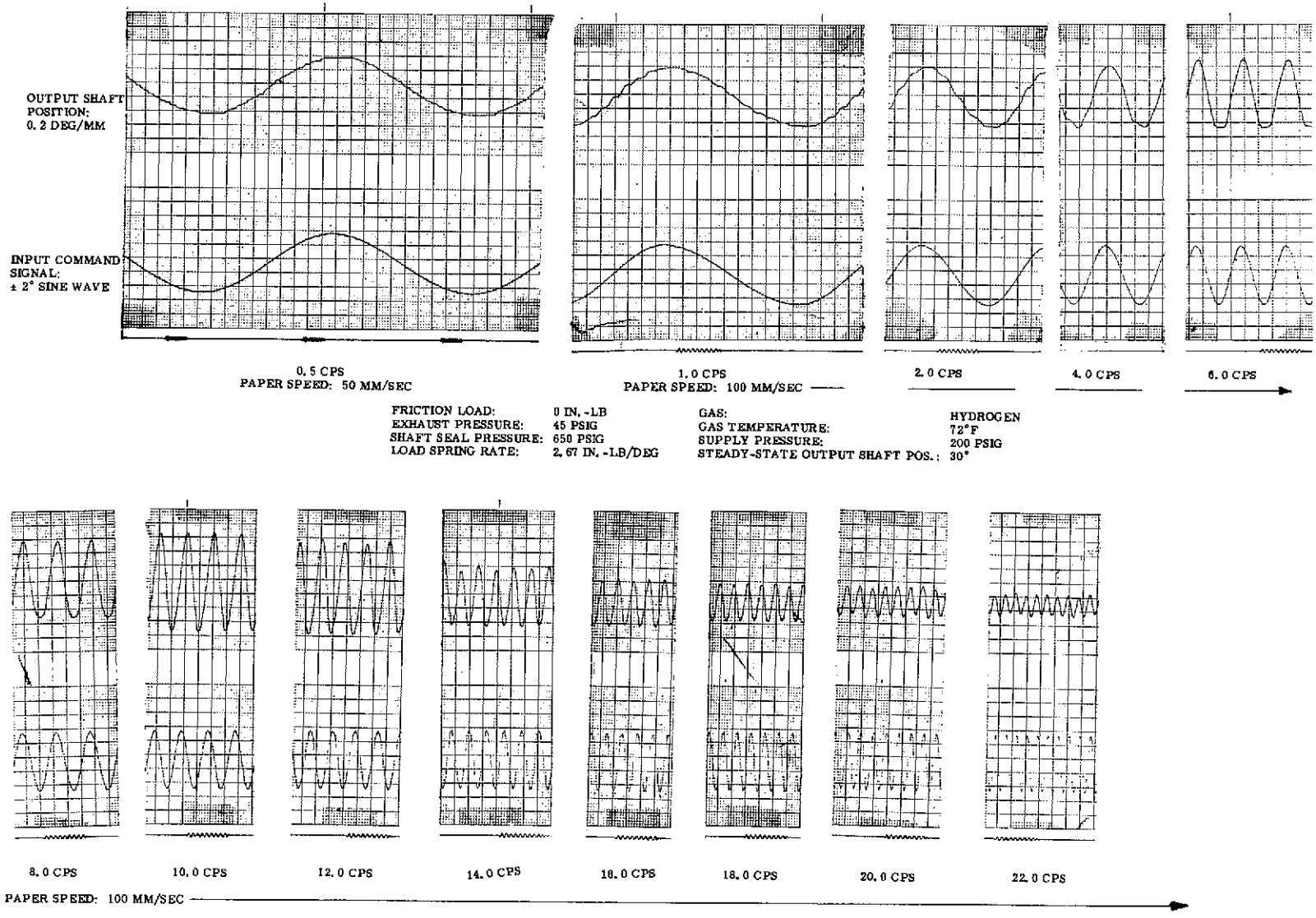


Figure 3-2. Frequency Response - Test Condition A

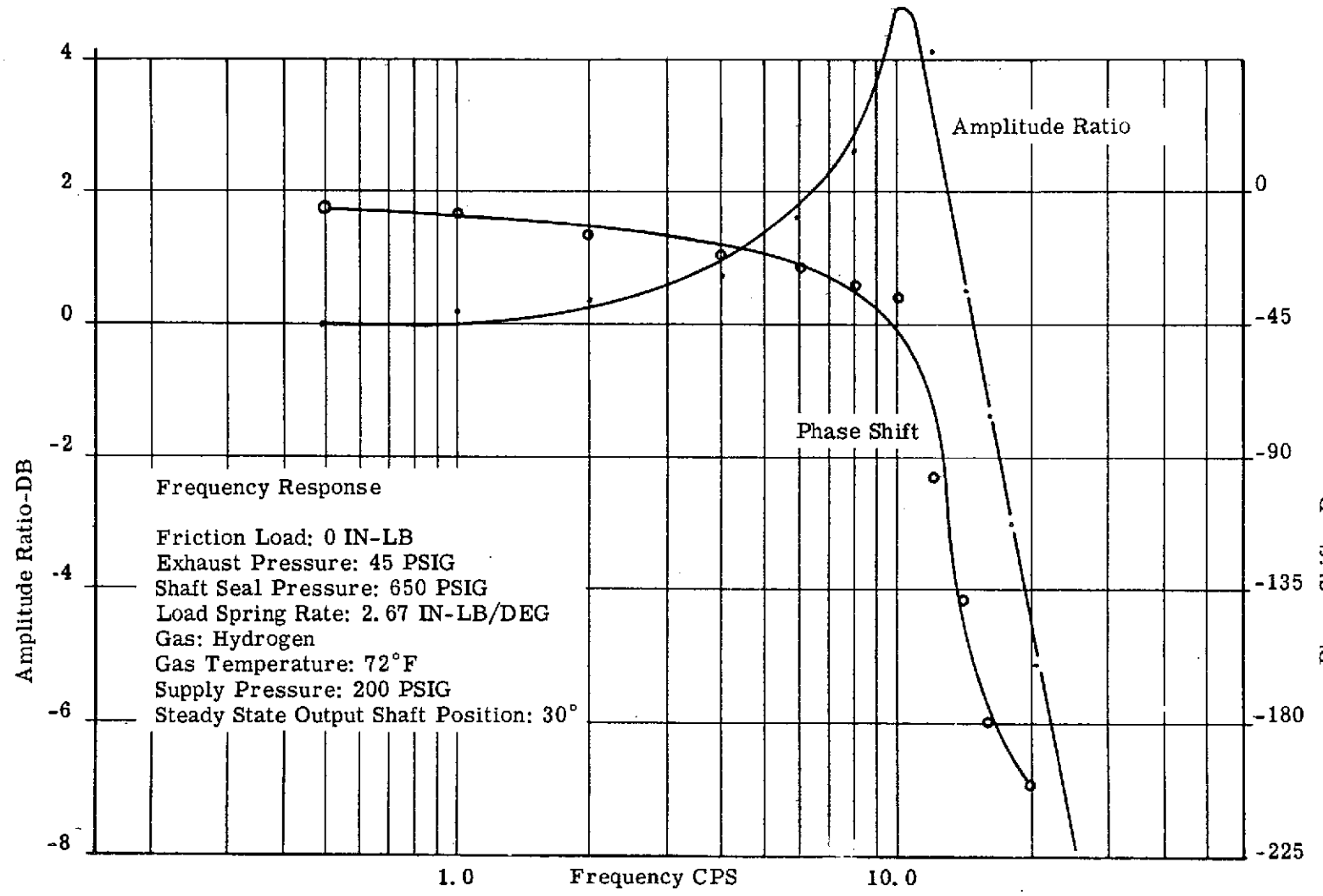
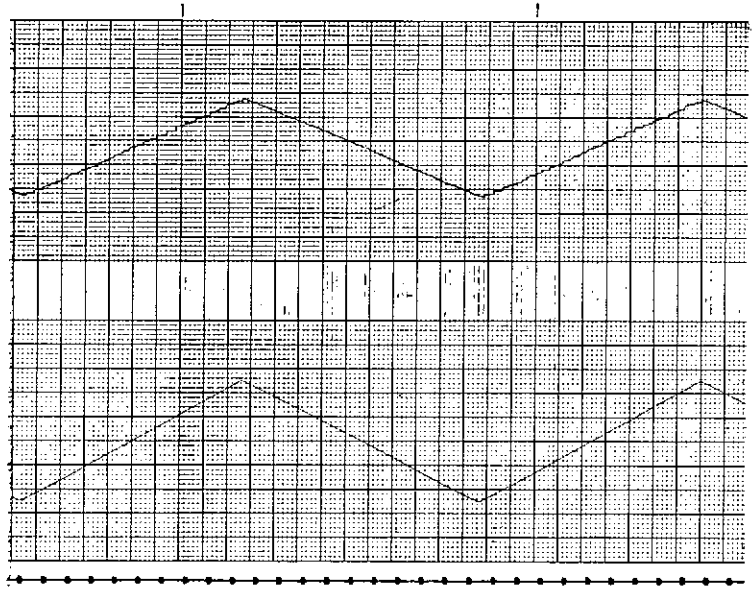


Figure 3-3. Amplitude Ratio and Phase Shift Versus Frequency

FRICTION LOAD	0 IN.-LB	LOAD SPRING RATE:	2.67 IN.-LB/DEG
EXHAUST PRESSURE:	45 PSIG	GAS:	HYDROGEN
SHAFT SEAL PRESSURE:	650 PSIG	GAS TEMPERATURE:	72°F
		SUPPLY PRESSURE:	200 PSIG

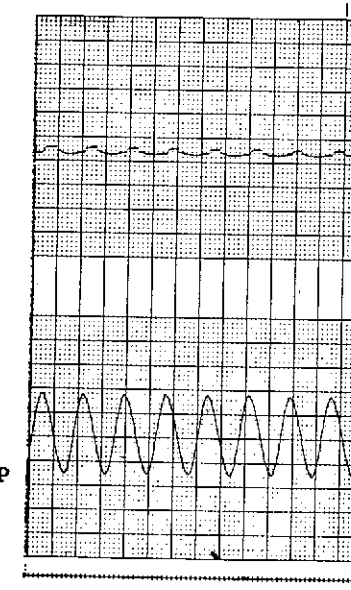


OUTPUT SHAFT POSITION: 0.5 DEGREE/MM

STEADY STATE OUTPUT SHAFT POSITION: 60°

INPUT COMMAND SIGNAL: ± 5 DEGREE RAMP AT 0.05 CPS

A DYNAMIC RESOLUTION
PAPER SPEED: 5 MM/SEC



OUTPUT SHAFT POSITION: 0.01 DEGREES/MM

STEADY STATE OUTPUT SHAFT POSITION: 60°

INPUT COMMAND SIGNAL: ±.08° 0.1 CPS SINE WAVE

B STATIC RESOLUTION
PAPER SPEED: 1 MM/SEC

Figure 3-4. Closed-Loop Performance of TPCV Actuator NT-C2, S/N 13 - Test Condition A

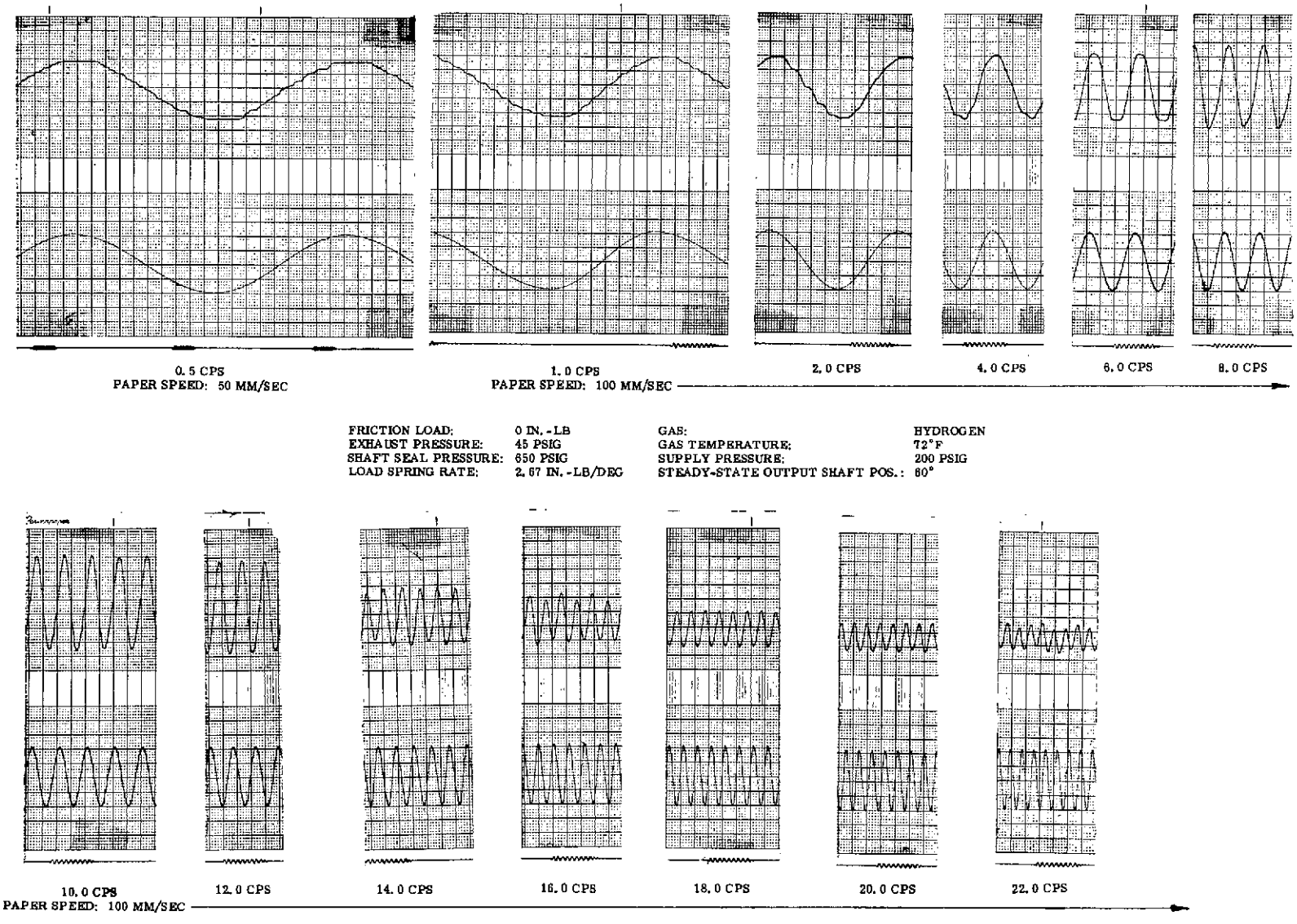


Figure 3-5. Frequency Response - Test Condition A

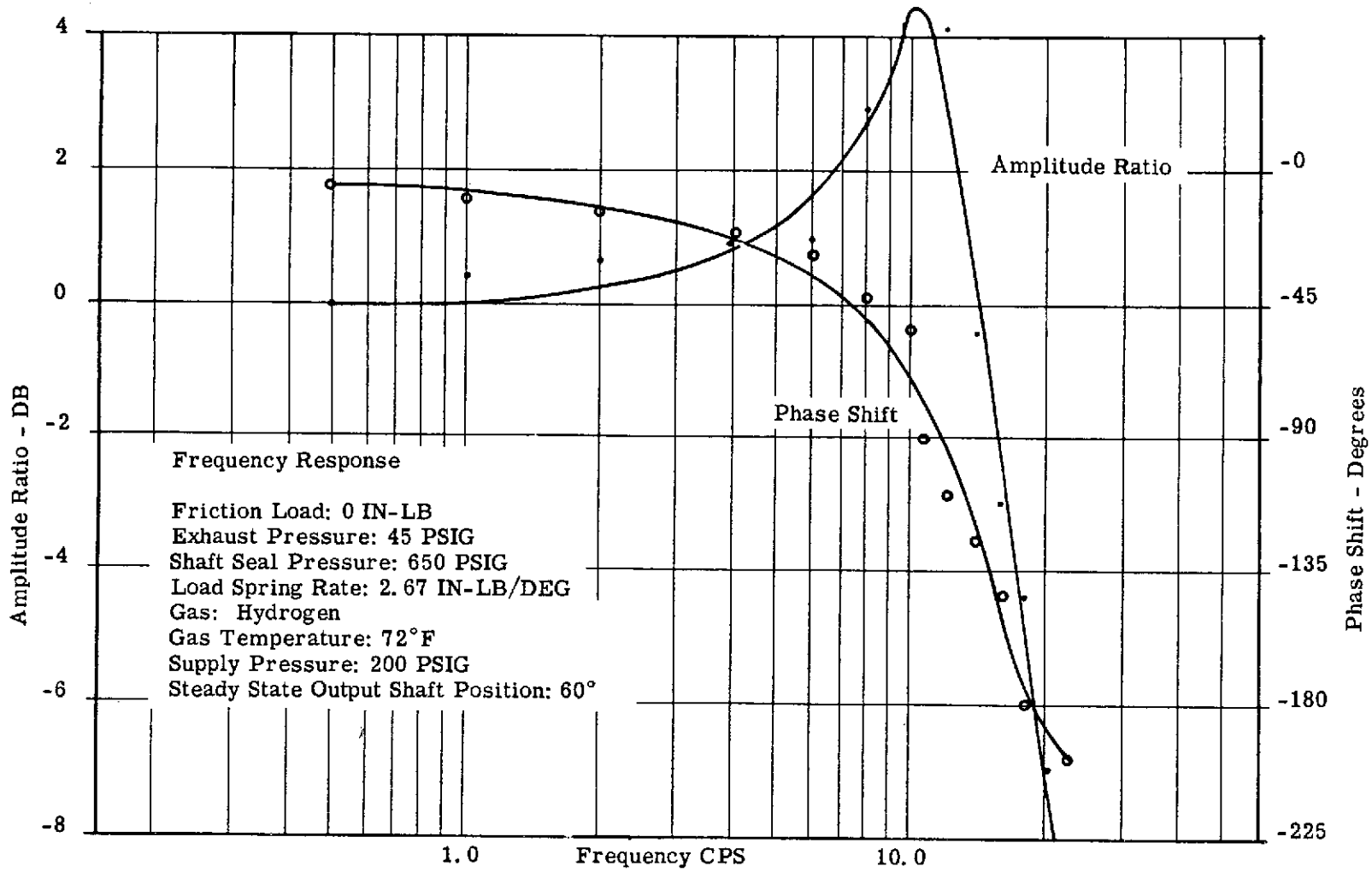
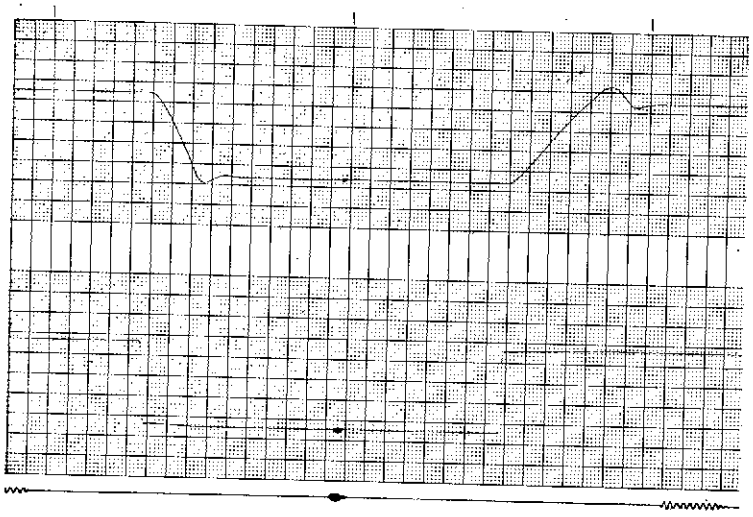


Figure 3-6. Amplitude Ratio and Phase Shift Versus Frequency

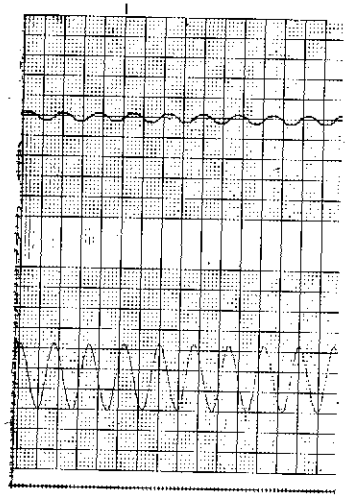


OUTPUT SHAFT POSITION: 2.0 DEGREE/MM

STEADY STATE OUTPUT SHAFT POSITION: 42°

INPUT COMMAND SIGNAL: 45 DEGREE STEP

A TRANSIENT RESPONSE AND SLEW VELOCITY
PAPER SPEED: 100 MM/SEC

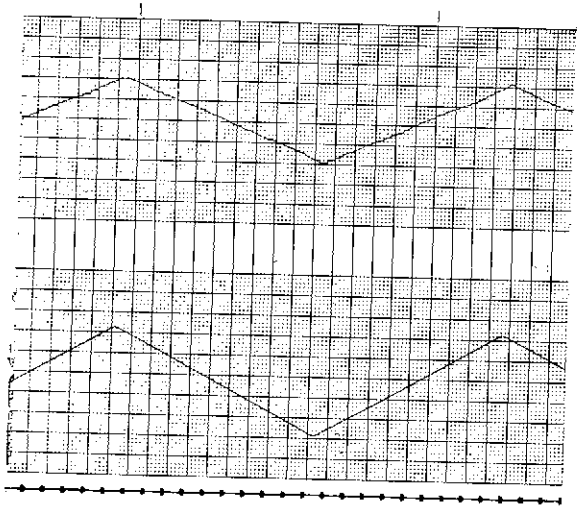


OUTPUT SHAFT POSITION: 0.01 DEGREES/MM

STEADY-STATE OUTPUT SHAFT POSITION: 30°

INPUT COMMAND SIGNAL: ± 0.05° 0.1 CPS SINE WAVE

B STATIC RESOLUTION
PAPER SPEED: 1 MM/SEC



OUTPUT SHAFT POSITION: 0.5 DEGREE/MM

STEADY STATE OUTPUT SHAFT POSITION: 30°

INPUT COMMAND SIGNAL: ± 5 DEGREE RAMP AT 0.05 CPS

C DYNAMIC RESOLUTION
PAPER SPEED: 5 MM/SEC

FRICTION LOAD:	0 IN.-LB	LOAD SPRING RATE:	2.67 IN.-LB/DEG
EXHAUST PRESSURE:	45 PSIG	GAS:	NITROGEN
SHAFT SEAL PRESSURE:	650 PSIG	GAS TEMPERATURE:	72°F
		SUPPLY PRESSURE:	200 PSIG

Figure 3-7. Closed-Loop Performance of TPCV Actuator NT-C2, S/N 13 - Test Condition B

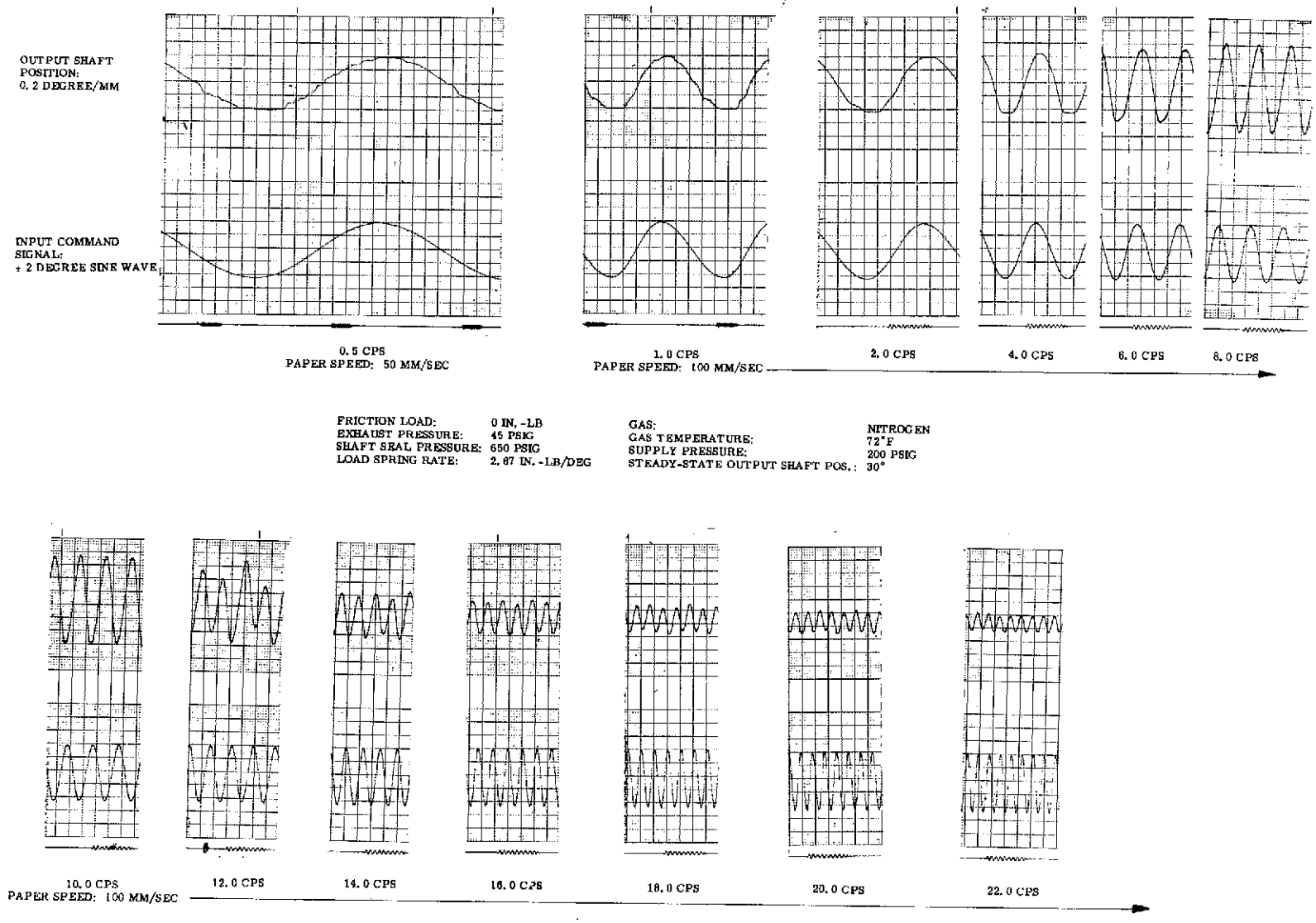


Figure 3-8. Frequency Response - Test Condition B

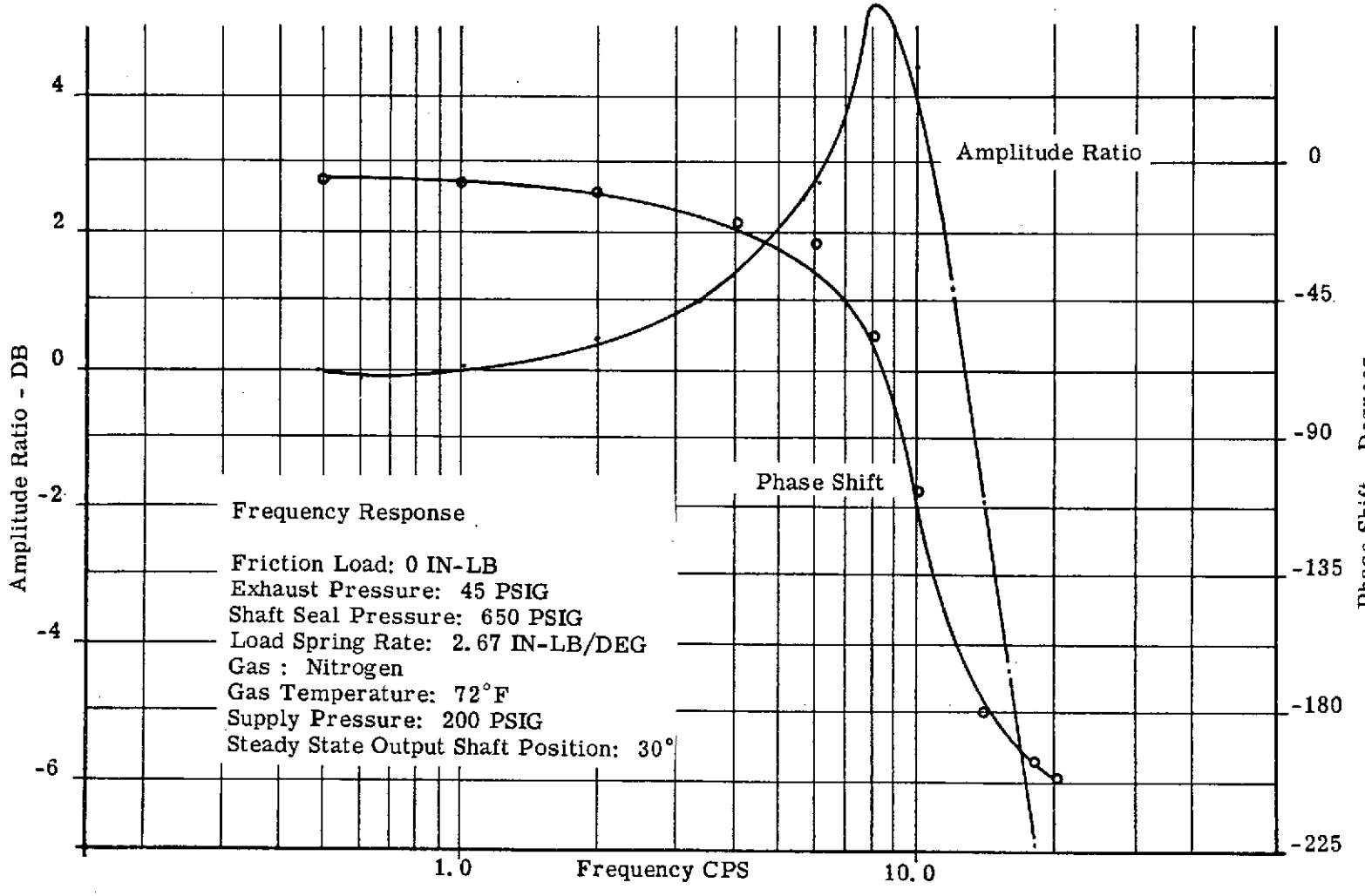
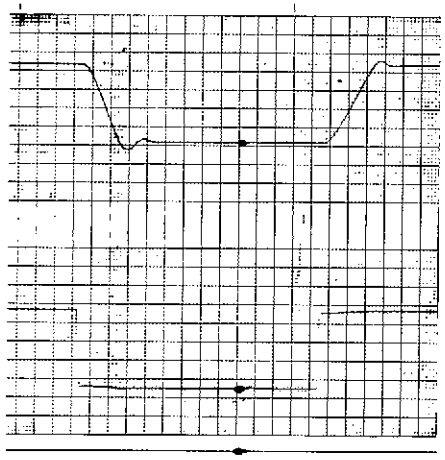


Figure 3-9. Amplitude Ratio and Phase Shift Versus Frequency

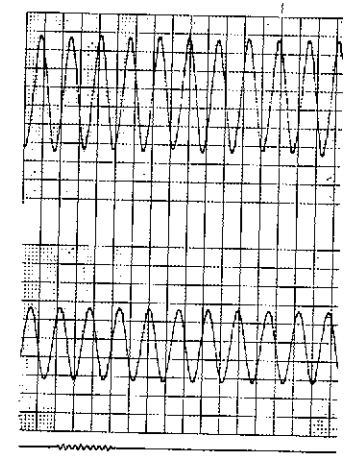


OUTPUT SHAFT POSITION: 2 DEGREES/MM

STEADY STATE OUTPUT SHAFT POSITION: 42°

INPUT COMMAND SIGNAL: 45 DEGREE STEP

A TRANSIENT RESPONSE AND SLEW VELOCITY
PAPER SPEED: 100 MM/SEC



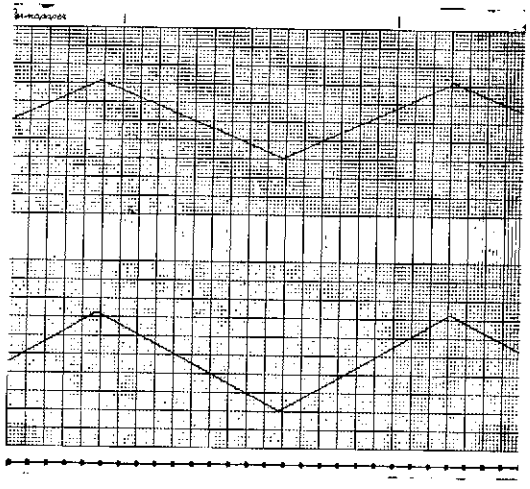
OUTPUT SHAFT POSITION: 0.2 DEGREE/MM

STEADY STATE OUTPUT SHAFT POSITION: 30°

INPUT COMMAND SIGNAL: ± 2 DEGREE SINE WAVE

B FREQUENCY RESPONSE
90° PHASE LAG AT ≈ 12 CPS
PAPER SPEED: 100 MM/SEC

FRICTION LOAD:	0 IN. -LB	LOAD SPRING RATE:	2.67 IN. -LB/DEG
EXHAUST PRESSURE:	45 PSIG	GAS:	HYDROGEN
SHAFT SEAL PRESSURE:	650 PSIG	GAS TEMPERATURE:	75°F
		SUPPLY PRESSURE:	200 PSIG

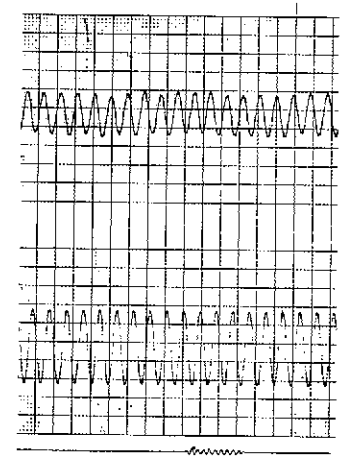


OUTPUT SHAFT POSITION: 0.5 DEGREE/MM

STEADY STATE OUTPUT SHAFT POSITION: 30°

INPUT COMMAND SIGNAL ± 5 DEGREE RAMP AT 0.05 CPS

C DYNAMIC RESOLUTION
PAPER SPEED: 5 MM/SEC



OUTPUT SHAFT POSITION: 0.2 DEG/MM

STEADY STATE OUTPUT SHAFT POSITION: 30°

INPUT COMMAND SIGNAL: ± 2° SINE WAVE

D FREQUENCY RESPONSE
180° PHASE LAG AT: ≈ 20 CPS
PAPER SPEED: 100 MM/SEC

Figure 3-10. Final Calibration Data